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P01/7700 0.00-0222352.7

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RSN/ME/P12225GB

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0222352.7

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

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Patents ADP number *(if you know it)*

8471476001

7422185002

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

TURBINE BLADE TURBULATOR COOLING DESIGN

5. Name of your agent *(if you have one)*

CRUIKSHANK & FAIRWEATHER

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19 ROYAL EXCHANGE SQUARE
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547002

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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Number of earlier application	Date of filing *(day / month / year)*

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CRUIKSHANK & FAIRWEATHER 25/09/02

12. Name and daytime telephone number of person to contact in the United Kingdom

Dr. R.S. Naismith
0141-221 5767

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TURBINE BLADE TURBULATOR COOLING DESIGN

The present invention relates to turbomachinery, and in particular, but not exclusively, to turbine blades for use in gas turbine engines.

Gas turbine engines are used in a number of applications, including aircraft propulsion systems and power generation systems and the like. Typical gas turbine engines generally consists of three components: a compressor, a combustion chamber, and a turbine unit, wherein the compressor and the turbine unit are mounted on the same shaft. In use, air is compressed by the compressor, is fed into the combustion chamber where it is mixed with fuel and the mixture is ignited, and the exhaust gases produced are then expanded through the turbine unit to drive the shaft and produce shaft work. In power generation applications, the shaft work produced is used to drive the compressor and turn electrical generators, often via a gearing system.

Conventional turbine units comprise a plurality of stages, each stage usually consisting of two sets of blades arranged in an annulus, the first set being stator or nozzle blades which are rotationally fixed with respect to the casing of the turbine, and the second set being rotor blades which are mounted on the shaft and rotate therewith. The number of stages in a turbine unit is selected in accordance with, for example, considerations of stage mechanical loading and thermodynamic performance. Additionally, the number of stages may be determined by the required pressure

ratio from turbine inlet to outlet.

Turbine efficiency is an important factor in the design of any gas turbine engine and one method of increasing the performance characteristics involves maximising the temperature of the gas at the turbine inlet. However, increasing the temperature of the gas used to drive the turbine produces serious mechanical and thermal stressing problems in the turbine blades, and the temperature of the gas is limited by the physical properties of the blade material, such as melting point and yield strength and the like.

Various advancements in materials have been made for use in high pressure and temperature turbines, however, these are extremely costly due to the complex formation process, for example, such as uni-directional crystallisation.

It is therefore common practice to minimise the thermal stress by cooling the blades during operation by passing cooling air bled from the compressor externally and internally of the blades, such that higher operational temperatures may be achieved, and the life span of the blades may be increased. A number of blade designs exist which allow a particular cooling air flow regime to be utilised to allow a combination of, for example, convection cooling, impingement cooling and film cooling in order to improve the heat transfer properties between the blade and the cooling air. However, the actual shape or design of a blade is often determined by a compromise between

aerodynamic and integrity requirements. Cooling primarily affects the integrity considerations both in terms of controlling the thermal stresses and maintaining the operating temperature of the material within acceptable limits to minimise creep and corrosion.

It is among the objects of the present invention to provide a turbine blade having improved cooling.

According to a first aspect of the present invention, there is provided a turbine blade having opposing pressure and suction side walls adjoining at leading and trailing edges of the blade, and defining at least one internal channel providing a flow passage for a cooling medium, said at least one channel including a plurality of turbulence promoting ribs mounted on a channel wall surface, wherein each rib comprises two rib portions joined at one end thereof to form a chevron junction, said chevron junction defining an angle of between 80 and 120 degrees between the two rib portions and being directed into the flow of the cooling medium within the at least one channel, and wherein each rib defines at least one gap therein.

Thus, the turbine blade provides for improved heat transfer between the blade and the cooling medium due to the presence and form of the ribs within the at least one channel.

Preferably, one rib portion is disposed at an angle of 120 degrees from the other rib portion, i.e. the chevron junction angle between the rib portions is preferably 120 degrees.

In a preferred embodiment of the present invention, the at least one channel has a substantially triangular cross-section. The at least one channel may alternatively have a substantially circular cross-sectional shape, or any cross-sectional shape as would be considered suitable by a person of ordinary skill in the art.

Preferably, adjacent ribs are aligned such that adjacent chevron junctions are longitudinally aligned with respect to the at least one channel. Alternatively, adjacent ribs may be misaligned such that adjacent chevron junctions are longitudinally offset.

Advantageously, the ribs may be mounted on opposing sides of the at least one channel, and each opposing rib may be laterally aligned with respect to the at least one channel. Alternatively, the ribs may be laterally offset.

Preferably, where adjacent ribs are circumfer-entially aligned, said at least one gap of each adjacent rib are longitudinally aligned with respect to the at least one channel. Alternatively, the at least one gap in each adjacent rib may be longitudinally offset.

In a preferred embodiment of the present invention, each rib defines at least two gaps, a first gap in one rib portion, and a second gap in the other rib portion.

Preferably, the centre of each gap in each rib portion is located approximately between 60% and 70%, and preferably around two thirds, along the length of each rib portion from the chevron junction.

Preferably, each rib extends substantially

perpendicular from the surface of the at least one channel.

Advantageously, adjacent ribs are spaced apart by between 4 and 6 mm, and more preferably by between 4 and 5 mm. Most preferably, adjacent ribs are spaced apart by 4.4 mm. It should be noted that the spacing between each rib is commonly referred to as the pitch.

Preferably, the ribs have a height of between 0.45 and 0.75 mm. More preferably, the ribs have a height of between 0.5 and 0.6 mm. Most preferably, the ribs have a height of 0.54 mm.

Advantageously, the ribs have a square cross-section and the rib gaps have a width substantially equal to the width of each rib.

Preferably, the at least one channel is located in the region of the leading edge. This arrangement is particularly advantageous as the at least one channel including the ribs having the chevron junction gives greatly enhanced cooling of the leading edge region where thermal degradation of the blade most commonly occurs. Advantageously, the at least one channel in the region of the leading edge is defined by the pressure wall, the suction wall and a web portion extending between the pressure and suction walls.

Preferably, when the ribs are located in at least one channel in the region of the leading edge, one rib portion is located on the pressure wall, and the other rib portion is located on the suction wall, and the chevron junction is aligned with the leading edge.

Alternatively, the at least one channel is located in a mid-passage of the blade, between the leading and trailing edges.

The blade may include a plurality of internal channels, at least one of which channels being located in the region of the leading edge, and at least one channel being located in a mid-passage of the blade, between the leading and trailing edges.

Conveniently, the at least one channel may be of a single pass form. Alternatively, the at least one channel may be of a serpentine form, or a combination of single pass and serpentine forms may be utilised.

Conveniently, the turbine blade further includes a root portion and a tip portion, wherein the pressure and suction walls and the leading and trailing edges extend from the root portion to the tip portion of the blade.

Preferably, the cooling medium is supplied to the blade via the root portion.

Preferably also, the root portion is of a fir-tree type. Alternatively, the root portion may be of a dove tail type, or any other type commonly used in the art.

Advantageously, the external surface of the turbine blade defines a plurality of apertures providing fluid communication between the at least one cooling channel and the exterior of the blade. Thus, cooling air internal of the blade may pass through the apertures to provide film cooling to the exterior surface of the blade.

Conveniently, the cooling medium is air, and preferably

compressed air fed from a compressor.

Advantageously, the turbine blade is for use in a gas turbine engine.

Preferably, the turbine blade is a rotor blade. Alternatively, the turbine blade may be a stator or nozzle blade.

More preferably, the turbine blade is a first stage rotor blade.

According to a second aspect of the present invention, there is provided a gas turbine engine including a plurality of turbine blades, at least one turbine blade having opposing pressure and suction side walls adjoining at leading and trailing edges of the blade, and defining at least one internal channel providing a flow passage for a cooling medium, said at least one channel including a plurality of turbulence promoting ribs mounted on a channel wall surface, wherein each rib comprises two rib portions joined at one end thereof to form a chevron junction, said chevron junction defining an angle of between 80 and 120 degrees between the two rib portions and being directed into the flow of the cooling medium within the at least one channel, and wherein each rib defines at least one gap therein.

According to a third aspect of the present invention, there is provided electrical generating means including a gas turbine engine, said gas turbine engine including a plurality of turbine blades, at least one turbine blade having opposing pressure and suction side walls adjoining

at leading and trailing edges of the blade, and defining at least one internal channel providing a flow passage for a cooling medium, said at least one channel including a plurality of turbulence promoting ribs mounted on a channel wall surface, wherein each rib comprises two rib portions joined at one end thereof to form a chevron junction, said chevron junction defining an angle of between 80 and 120 degrees between the two rib portions and being directed into the flow of the cooling medium within the at least one channel, and wherein each rib defines at least one gap therein.

These and other aspects of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a longitudinal cross-sectional view of a turbine blade in accordance with one embodiment of the present invention;

Figure 2 is a longitudinal cross-sectional view of an internal channel of the turbine blade of Figure 1; and

Figure 3 is a perspective diagrammatic view of the channel shown in Figure 2.

Reference is first made to Figure 1 of the drawings in which there is shown a cross-sectional view of a turbine blade, generally indicated by reference numeral 10, for use in a gas turbine engine in accordance with one embodiment of the present invention. The blade 10 is a first stage rotor blade and has opposing pressure and suction side walls adjoining at a leading edge 12 and a trailing edge 14 of the

blade 10. The turbine blade 10 defines a number of internal channels 16, which channels provide a flow passage for a cooling medium, such as compressed air, to cool the blade 10 while in use. The blade also includes a root portion 18 and a tip portion 20, wherein the cooling medium is supplied to the internal channels 16 through the root portion 18. As shown, the root portion 18 is of a fir-tree type.

The internal channels 16 consist of a leading edge channel 22 and a number of mid-passage channels 24 located between the leading and trailing edges 12, 14 of the blade 10. The leading edge channel 22 is substantially triangular in cross-section and is a single pass channel aligned substantially parallel to the leading edge 12, wherein cooling air enters from the root portion 18, flows through the leading edge channel 22, and exits the blade through an aperture 21 in the tip portion 20 of the blade 10. The mid-passage channels 24 on the other hand are of a serpentine form, and provide a convoluted flow path for the cooling medium or air. Air flowing through the mid-passage channels 24 may exit the interior of the blade via apertures providing fluid communication between the channels 24 and the exterior of the blade, such as apertures 26 in the region of the trailing edge 14 of the turbine blade 10 or an aperture 23 in the tip portion 20 of the blade 10.

In the embodiment shown, the leading edge channel 22 includes a plurality of upstanding turbulence promoting ribs which seek to improve the heat transfer between the surfaces of the blade 10 and the cooling medium. The ribs 28 are

shown in Figure 2 in which there is shown an enlarged longitudinal cross-sectional view of the leading edge channel 22 of the turbine blade 10 of Figure 1.

Each rib 28 comprises first and second rib portions 30, 32, which portions 30, 32 join at one end to form a chevron junction 34, wherein the arrangement is such that the first rib portion 30 is disposed at an angle 36 of around 120 degrees from the second rib portion 32. The chevron junction 34 of each rib is directed into the flow of the cooling medium, the flow direction being indicated in Figure 2 by arrow 38. Additionally, the chevron junction 34 of each adjacent rib 28 are longitudinally aligned with respect to the channel flow direction 38.

Referring still to Figure 2, each rib includes two gaps 40, 42 to further increase the turbulence in the flow of cooling medium, wherein the gaps 40, 42 of each rib 28 are longitudinally aligned with respect to the channel 22.

In the preferred embodiment shown, adjacent ribs are separated from each other, i.e. the rib pitch, by around 4.4 mm and extend substantially perpendicular from the surface 44 of the channel 22 by a height of approximately 0.54 mm.

Additionally, the ribs 28 have a square cross-section and the rib gaps 40, 42 have a width substantially equal to the width of each rib 28.

Furthermore, the centre of each gap 40,42 in each rib 28 is located approximately two thirds along the length of each rib portion 30, 32 respectively from the chevron junction 34.

Reference is now made to Figure 3 of the drawings in which a perspective diagrammatic view of the channel 22 is illustrated. As shown, the channel 22 is triangular in cross-section and includes a plurality of ribs 28, each comprising first and second rib portions 30,32, which portions 30,32 join at one end to form a chevron junction 34. The chevron junctions 34 are directed into the direction of flow 38 of cooling medium, and each junction 34 is aligned with the leading edge 12 of the blade 10.

In the embodiment shown, the first rib portion 30 is mounted on the suction wall 50, and the second rib portion 32 is mounted on the pressure wall 52.

As noted before, each rib includes two gaps 40, 42 which are longitudinally aligned with respect to the channel 22.

It should be obvious to a person of skill in the art that the above described embodiment is merely exemplary of the present invention and that various modifications may be made thereto without departing from the scope of the present invention. For example, The chevron junction 34 may define any suitable angle between first and second rib portions 30, 32, and may be directed in line with the flow of cooling medium. Additionally, any number of gaps may be provided in the ribs, and the gaps of each adjacent rib may be offset or staggered. Furthermore, the rib pitch may vary or be selected as required and is not necessarily restricted to the value given above. Similarly, the height of each rib may vary.

The ribs of the turbine blade of the present invention have been shown in the accompanying representations in the leading edge channel 22. However, the particular form of ribs described herein may be used within the mid-passage channels 24, either in addition to or in place of those in the leading edge channel.

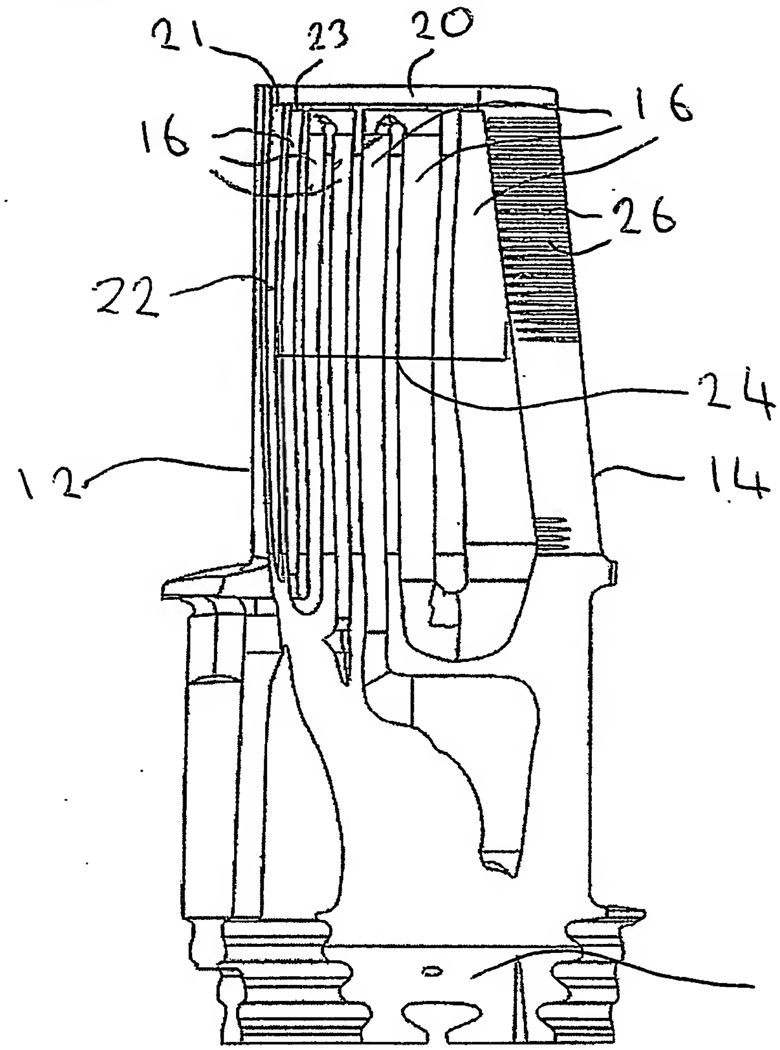

FIGURE 1

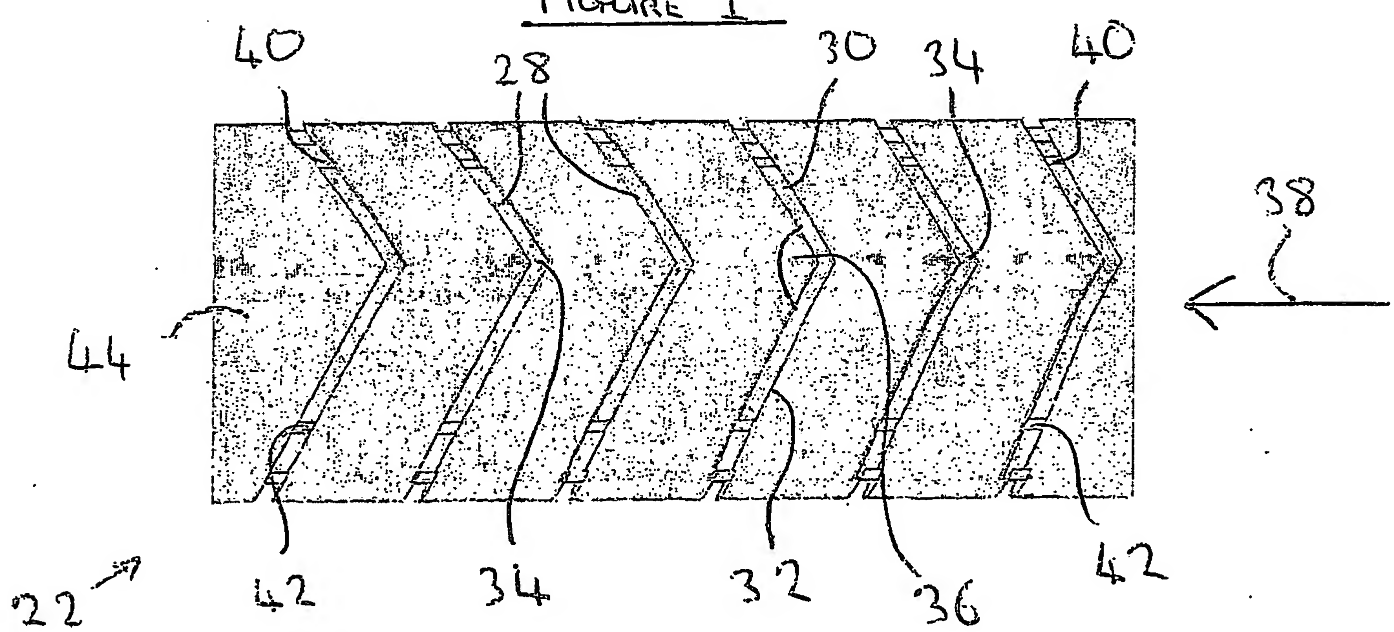

FIGURE 2

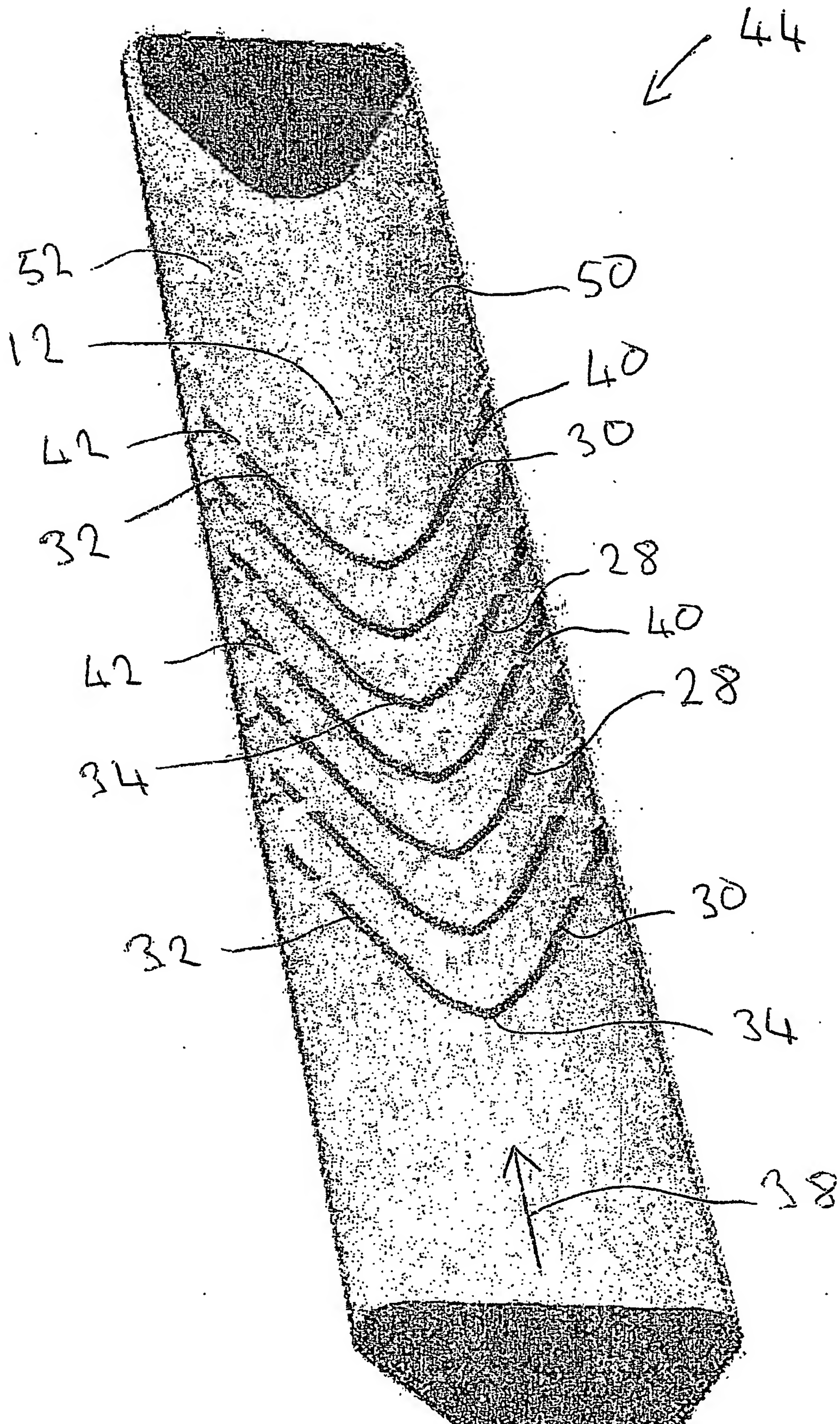

Figure 3